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SUBTASK MEMORANDUM

Task: 1.3 Adequacy and validity of meteorological measurements

Subtask: 2 Evaluate the surface mechanical sensor performance relative to the sonics at Angiola

From: Bob Baxter/David Bush

Date: 2/17/04

The following presents a review of sonic and conventional mechanical meteorological data at the Angiola site, with an emphasis placed on reviewing data during periods of stagnation. Only sonic data collected between December 23 and December 31, 2000 were made available by NOAA for the comparison. In addition, while sonic data were provided for three levels (26-m, 47-m, and 96-m), the data for the 96-m level was missing portions of each hour after December 24, 2000, rendering it unusable for 5-minute averaging and leaving only a short period of valid data for comparison. Moreover, during the period of available data, wind speeds were typically greater than 4 m/s and wind directions during this period were relatively persistent from the west and northwest. Thus, the usefulness of the 96-m data for comparative purposes is limited. As a consequence, the remainder of this discussion is limited to the 26-m and 47-m level data. Since the mechanical sensors were mounted slightly lower than the sonic sensors, at 23 meters and 43 meters, the remainder of this discussion will refer to the levels as 25-m and 45-m.

The sonic data received from NOAA required considerable processing in order to make the data comparable with the mechanical data. The task was made more difficult in that NOAA could not provide any definitive information regarding the orientation of the sonic sensors. NOAA was monitoring primarily for turbulence, and since all results were normalized against the mean wind direction, the actual orientation of the sensor was not required. It was therefore necessary to estimate a correction to actual orientation for the sonic measurements. After processing the averages, comparison of the sonic and mechanical data showed dramatic differences between the wind directions reported by the two methods. However, the two sets of data were highly correlated, and a visual review of the data showed that the sonic data could be converted to coordinates comparable to the mechanical data by multiplying by a slope of –1 and adding 230°. Further discussions with NOAA revealed the fact that the sensors, for convenience, had been mounted upside down, thus accounting for the –1 slope. Furthermore, the 230° intercept is consistent with the sensor boom orientation at 320°, which appears to be the actual boom orientation based on review of existing site documentation and photos. In contrast, it appears that the mechanical sensors were mounted on booms extending 260° from the tower.

Once the sonic data were adjusted, the two data sets compared very well. 5-minute averages were available for both data sets, and the remainder of this discussion deals with comparison of the 5-minute averages. **Figures 1 and 2** compare wind direction at the two levels, with each figure separately showing data for wind speeds less than 1 m/s and for wind speeds greater than 1 m/s. **Table 1** summarizes the results of these comparisons. For wind speeds greater than 1 m/s, the agreement between the two methods is excellent. Not unanticipated, the agreement is not as good for periods when the wind speed is less than 1 m/s, though the general 1 to 1 relationship prevails.

		WS 1 m/s	**WS < 1 m/s**
25-m	Relative difference (degrees)	1.6	5.0
	Standard deviation (degrees)	16.0	51.4
	Correlation (r)	0.986	0.890
	N	1619	388
45-m	Relative difference (degrees)	-1.6	-2.2
	Standard deviation (degrees)	9.4	36.0
	Correlation (r)	0.995	0.925
	N	1489	432

Table 1. Wind direction comparison statistics (mechanical vs. sonci)

Aside from making the data sets comparable, the importance of the orientation of the sensors becomes apparent when viewing **Figure 3**. While the plots demonstrate the overall good agreement between the two methods, there is a notable area of disagreement for winds coming 120° to 160°. Wind speeds from this sector, which is centered on 140° (exactly 180° downwind of the tower relative to the sonic sensor), appear to be underreported by the sonic sensors relative the mechanical sensors. The obvious conclusion is that the tower obstructs the flow, reducing the wind speed. A similar is phenomenon is noted in the 70° to 100° sector, immediately upwind of the mechanical sensors located at 260°. Here, the sonic wind direction readings are higher than the obstructed mechanical readings.

As the wind rose plots show, interference by the tower is minimized by placing the sensors towards the prevailing winds out of the northwest. The dominance of this prevailing wind direction is less pronounced during light winds, as demonstrated in **Figure 4**. However, the general pattern of agreement persists at light wind speeds, including the effects of the tower obstruction, though to a lesser degree.

Figures 5 and 6 present time series plots comparing wind speed and wind direction measurements at the 25-m level for the two methods over a period of 24 hours that include the longest extended period of low wind speeds during which sonic data were available. Noticeable immediately are several periods with significant differences in the reported wind speed. These periods, however, are associated with winds from the obstructed directions. Once these periods are removed (**Figure 7**), very good agreement is noted between the two methods, and, for the remaining wind speed comparison, winds in the obstructing directions have been removed in order to better compare the two methods. For both wind speed and wind direction, both methods reveal similar temporal structure, with neither method obviously more sensitive in reporting small-scale changes. **Figures 8 and 9** present data from the 45-m level, showing similar agreement.

In further reviewing the performance of the methods at low wind speeds, it was noted that there were nine instances (about 0.5% of the dataset) at the 45-m meter level where the reported mechanical wind speed for the 5-minute period was 0 m/s. These are instances where the sensor propeller did not turn, due to the start threshold of the sensor. The average sonic anemometer wind speed reading for these instances was 0.32 m/s. For 42 of the 45 1-minute periods during these instances the average sonic wind speed was less than 0.45 m/s. Three 1-minute averages were approximately 0.6 m/s, though for a 5-minute period immediately after these slightly higher readings, the wind speed did not exceed 0.19 m/s.

Though this all appears consistent with the starting threshold for the mechanical anemometer (<0.5 m/s), the fact that the sonic wind speed was noticeable upscale during periods reported as 0 m/s was further investigated. **Table 2** demonstrates that for the data sets in general, no noticeable bias is introduced into the data by the higher starting threshold of the mechanical sensors. In fact, for the 45-m level, slightly higher average mechanical reading are observed at wind speeds less than 0.3 m/s, though the reason for this is not apparent.

		Wind speed relative difference (mechanical - sonic) (m/s)				
		All	**WS 1 m/s**	**WS < 1 m/s**	**WS < 0.5 m/s**	**WS < 0.3 m/s**
25-m	Average	-0.035	-0.054	0.059	0.031	0.014
	Std Dev	0.498	0.529	0.273	0.237	0.167
	N	1546	1288	258	56	14
45-m	Average	-0.005	-0.006	-0.001	0.036	0.126
	Std Dev	0.249	0.248	0.252	0.276	0.239
	N	1676	1286	393	105	36

Table 2. Mechanical versus sonic wind speed comparison

To further investigate the overall effect that these apparently minor differences might have on the use of the data, two back trajectories were generated using each of the methods. Two 12-hour periods under basically stagnant conditions were chosen for the comparison. The first period, shown in **Figure 10,** includes winds predominantly from the northwest, limiting obstruction inaccuracies as describe above. Back-trajectories were generated using winds from both the 25- and 45-m levels. While the source position ends up differing by approximately 5 km for both levels, the trajectories are very similar. Furthermore, differences due to the methods are much smaller than differences introduced by the choice of wind measurement level. Figure 11 is a similar plot for a period when winds were more out of the east, leading to periods when the tower acted as an obstruction for one or both of the sensors. Results for the 25-m level are similar to those for the unobstructed period, with similar relative source position differences and trajectory tracks. The differences at the 45-m level are more noticeable, though, once again, there is more variability due to level choice than to method choice.

In conclusion, there appears to be very little significant difference between the mechanical and sonic wind data. No significant biases are noted between the methods, even at very low wind speeds, and both methods show similar temporal structure.

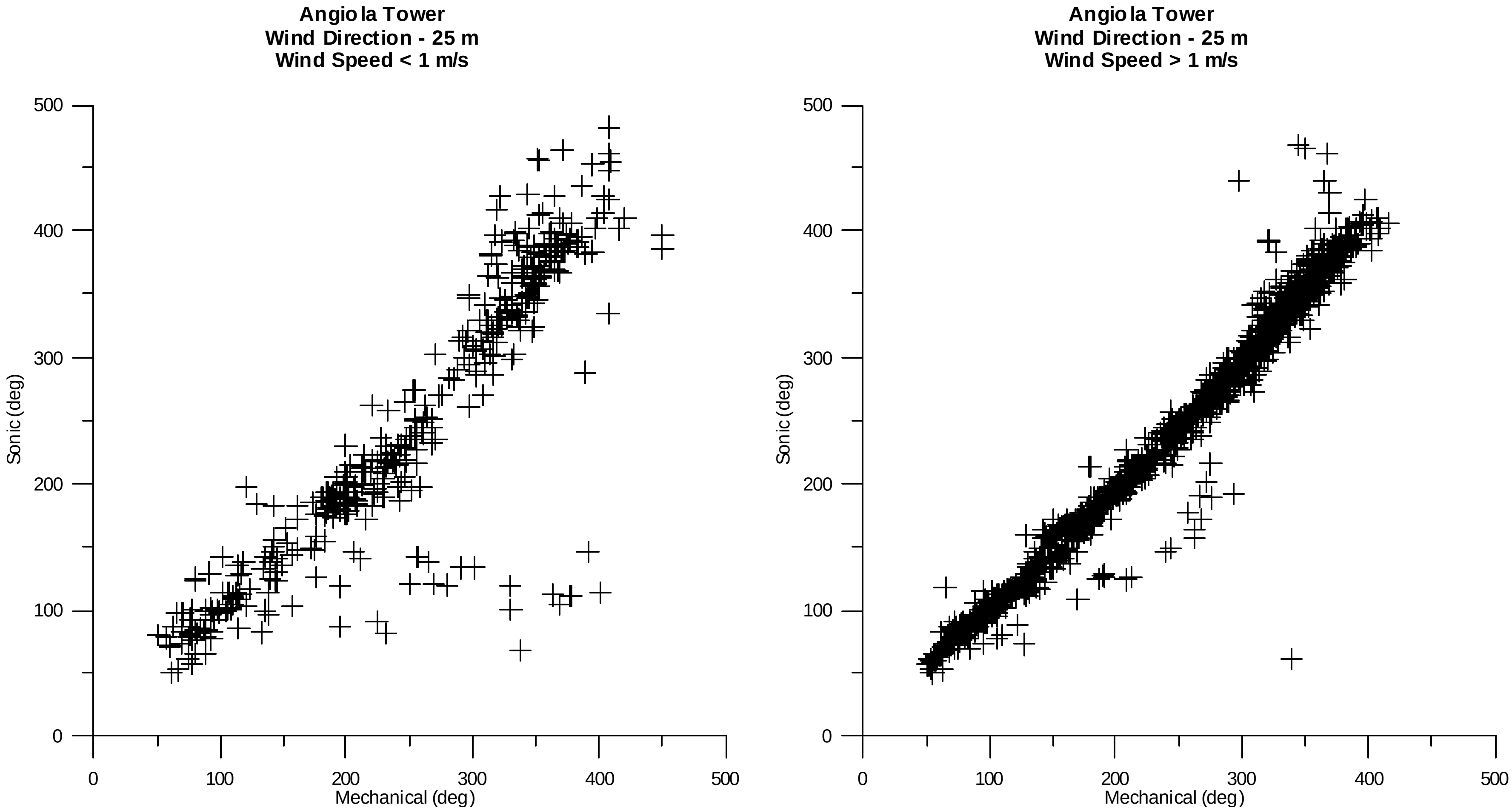


Figure 1. Sonic versus mechanical wind direction comparison – 25-m level

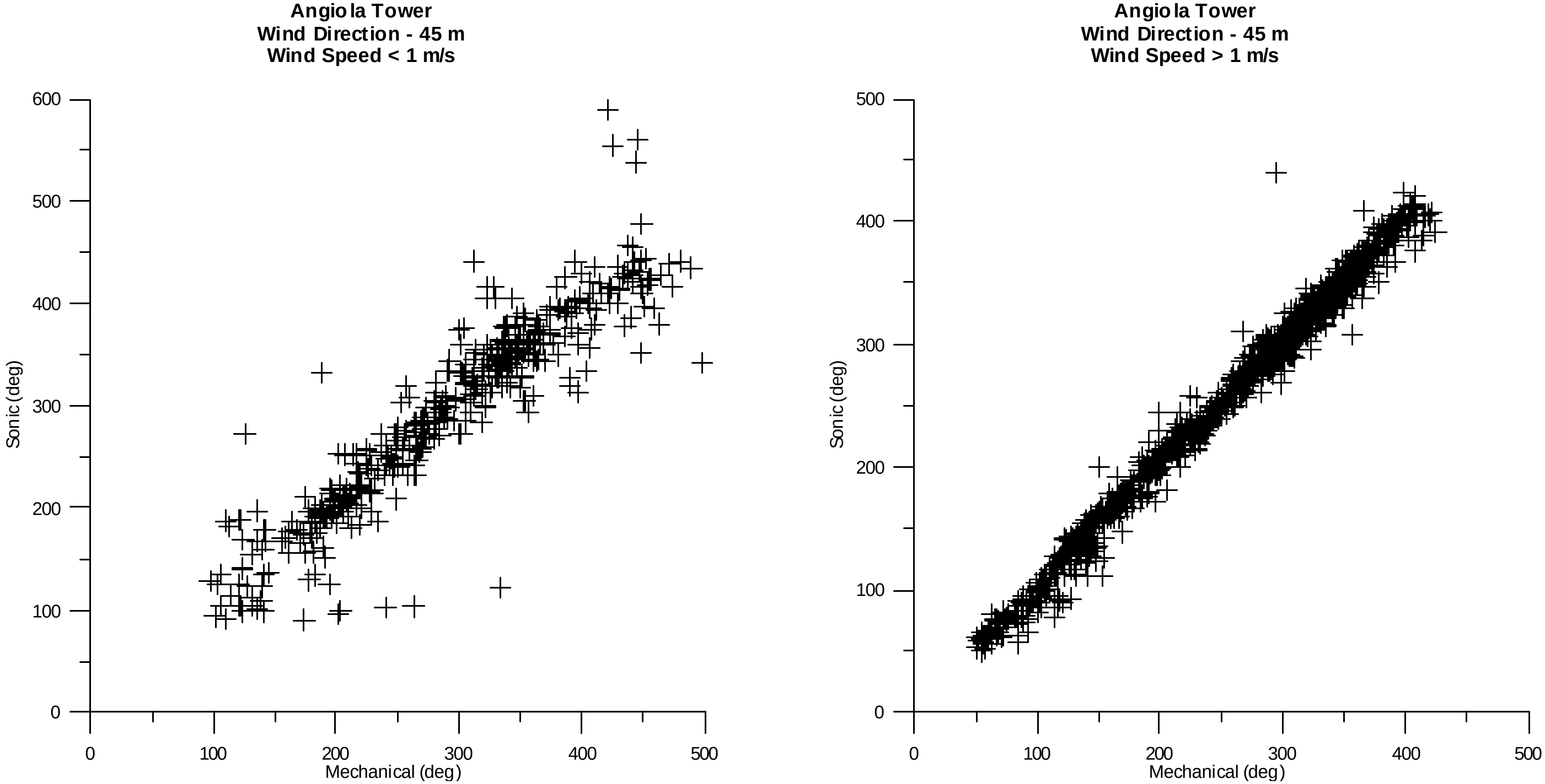
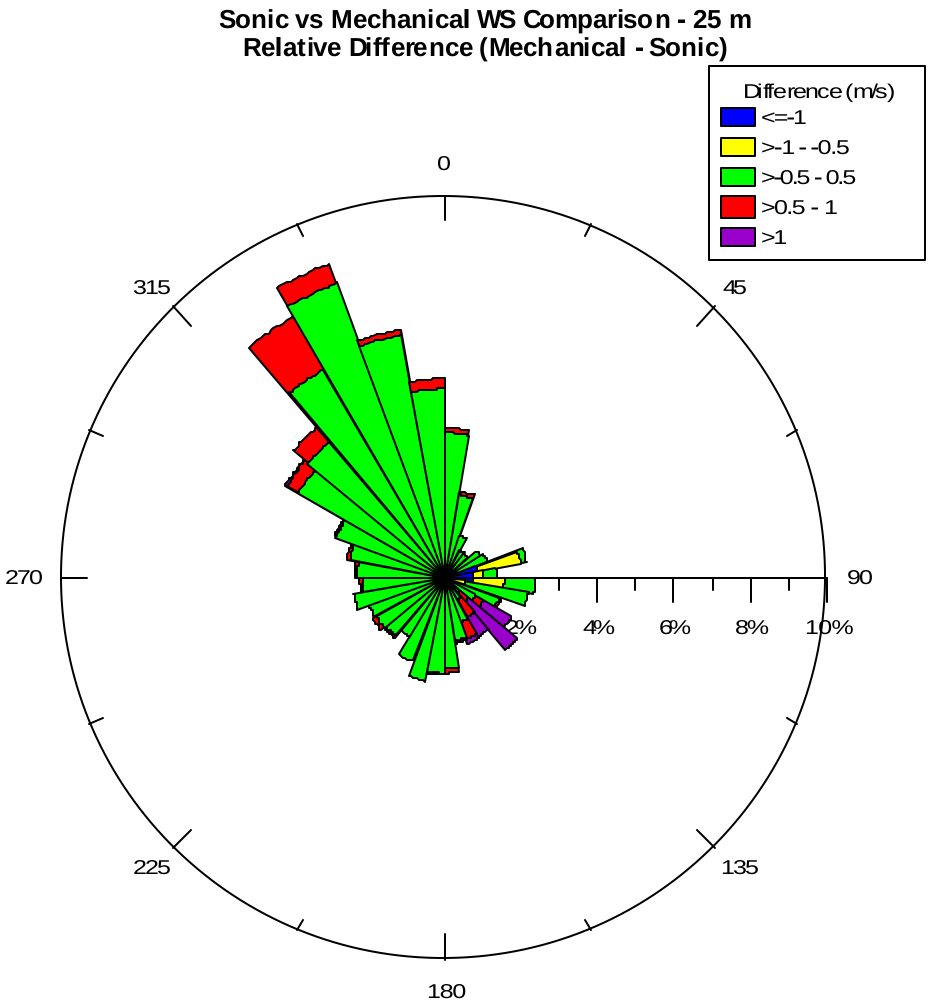


Figure 2. Sonic versus mechanical wind direction comparison – 45-m level



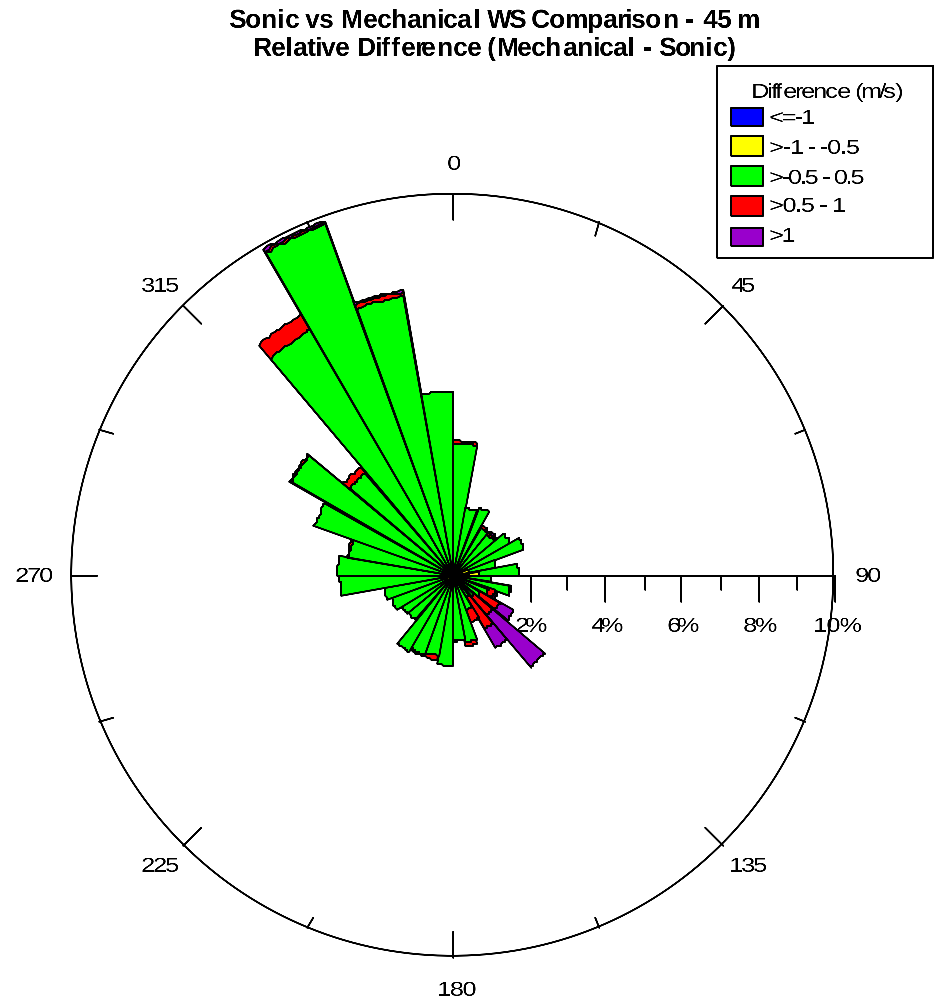
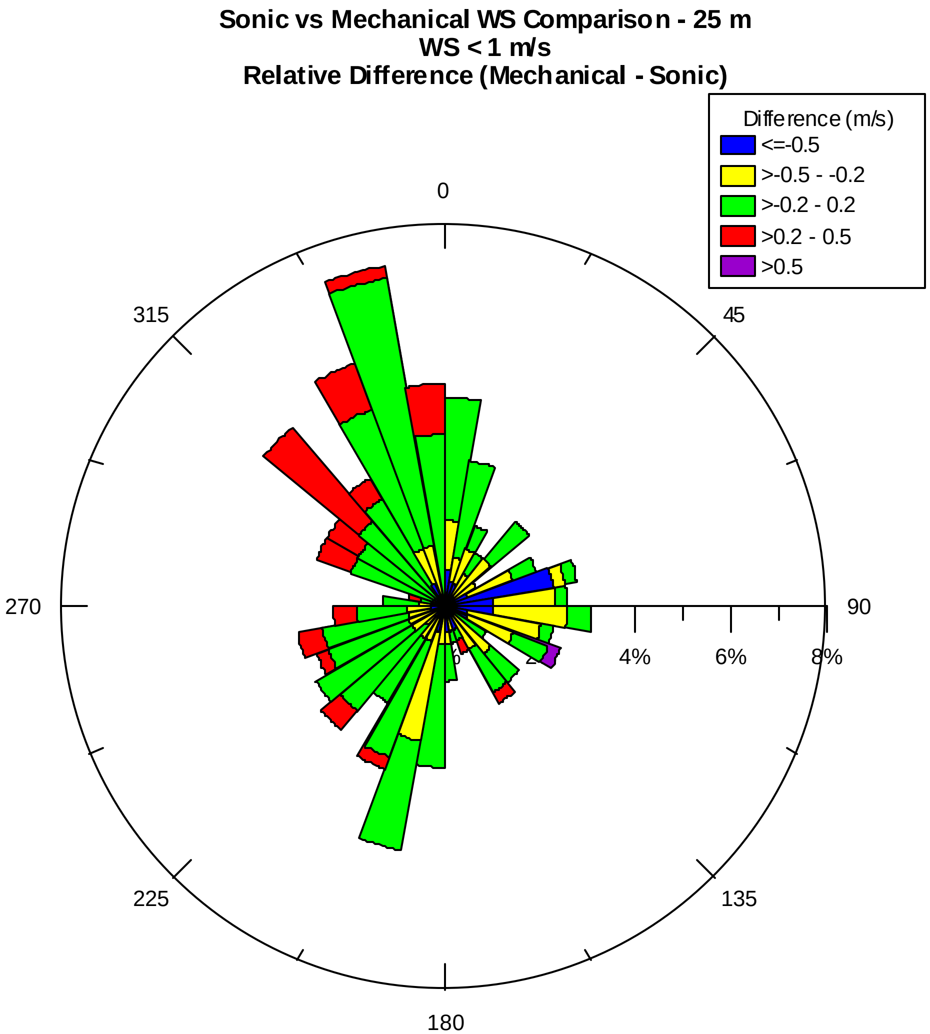


Figure 3. Wind rose plots of differences between sonic and mechanical wind speed measurements.



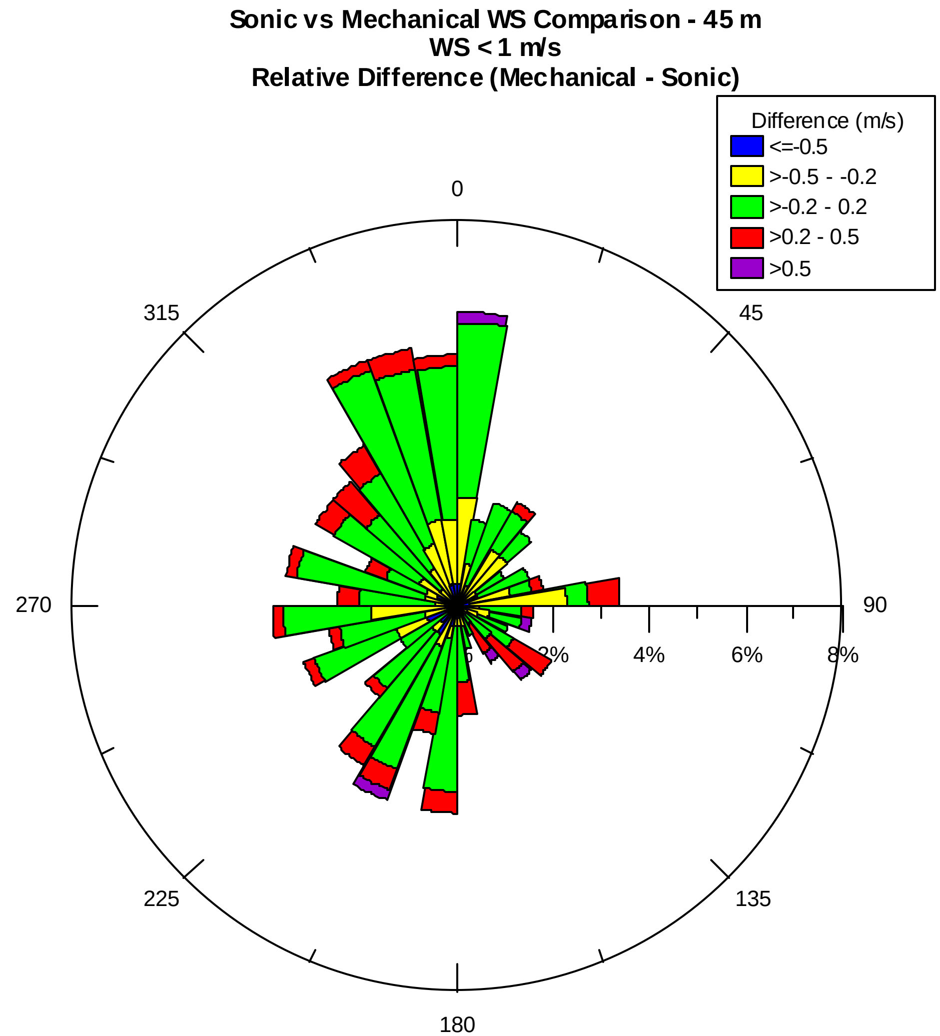


Figure 4. Wind rose plots of differences between sonic and mechanical wind speed measurements – wind speeds < 1 m/s.

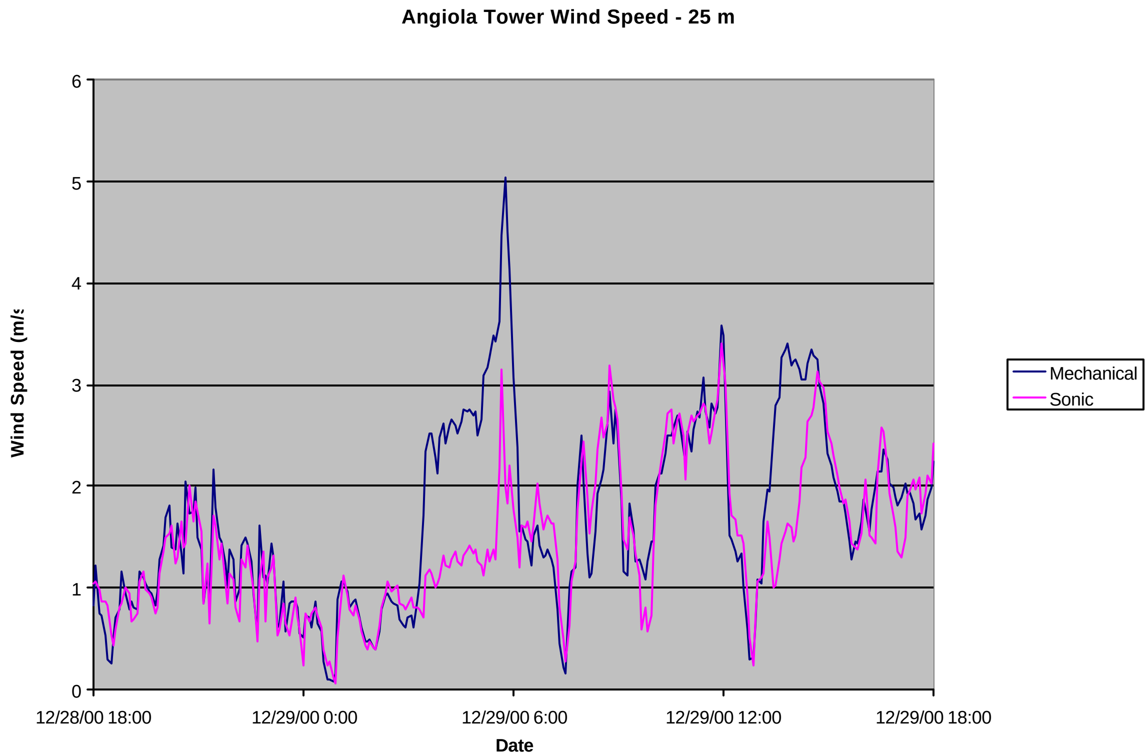


Figure 5. Wind speed comparison – 25-m level.

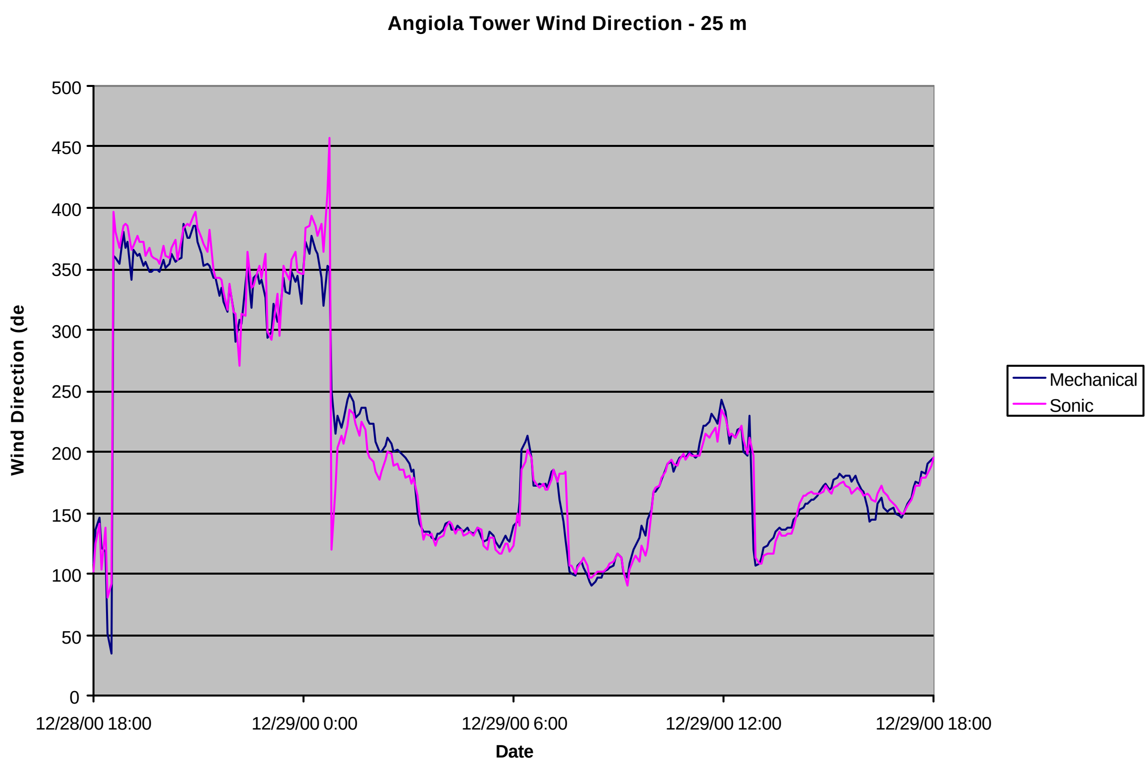


Figure 6. Wind direction comparison – 25-m level.

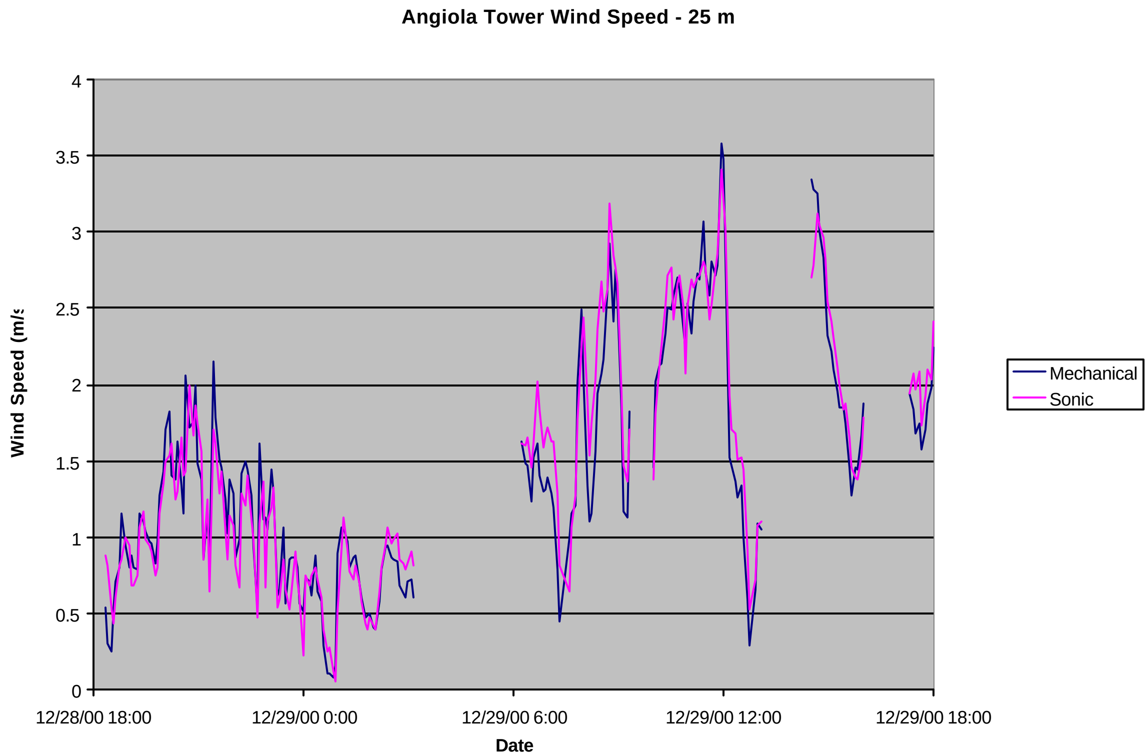


Figure 7. Wind speed comparison – 25-m level, obstruction directions removed

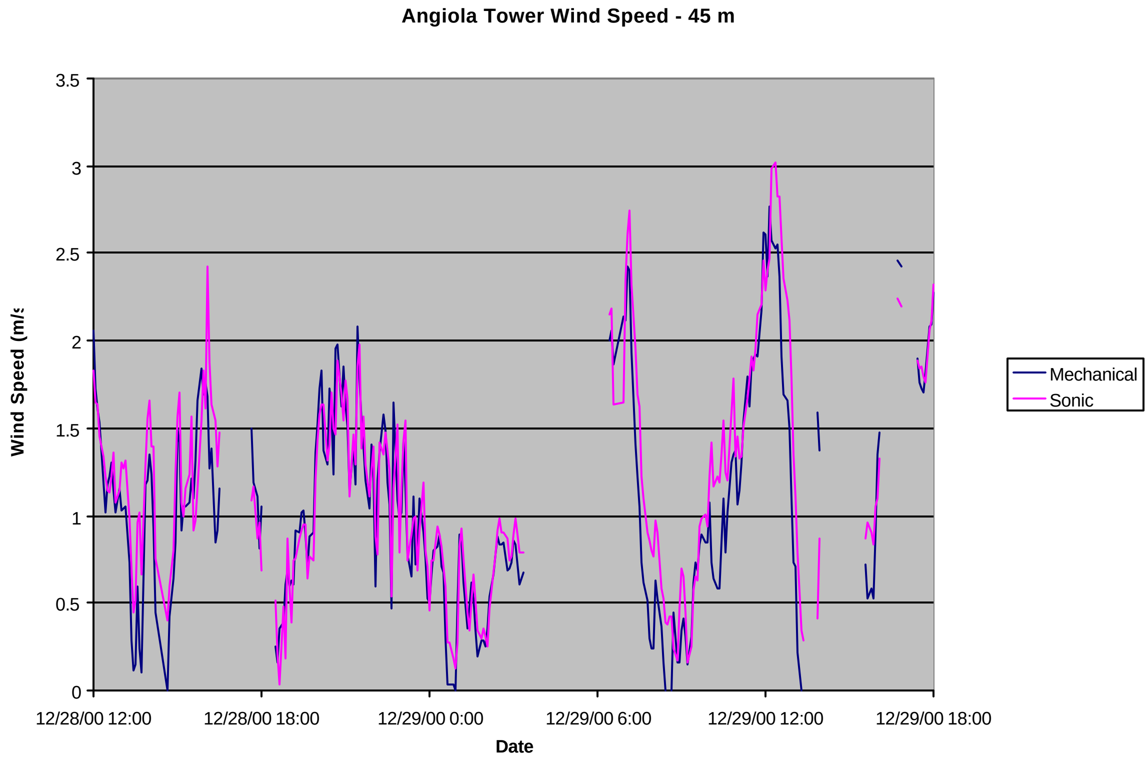


Figure 8. Wind speed comparison – 45-m level, obstruction directions removed.

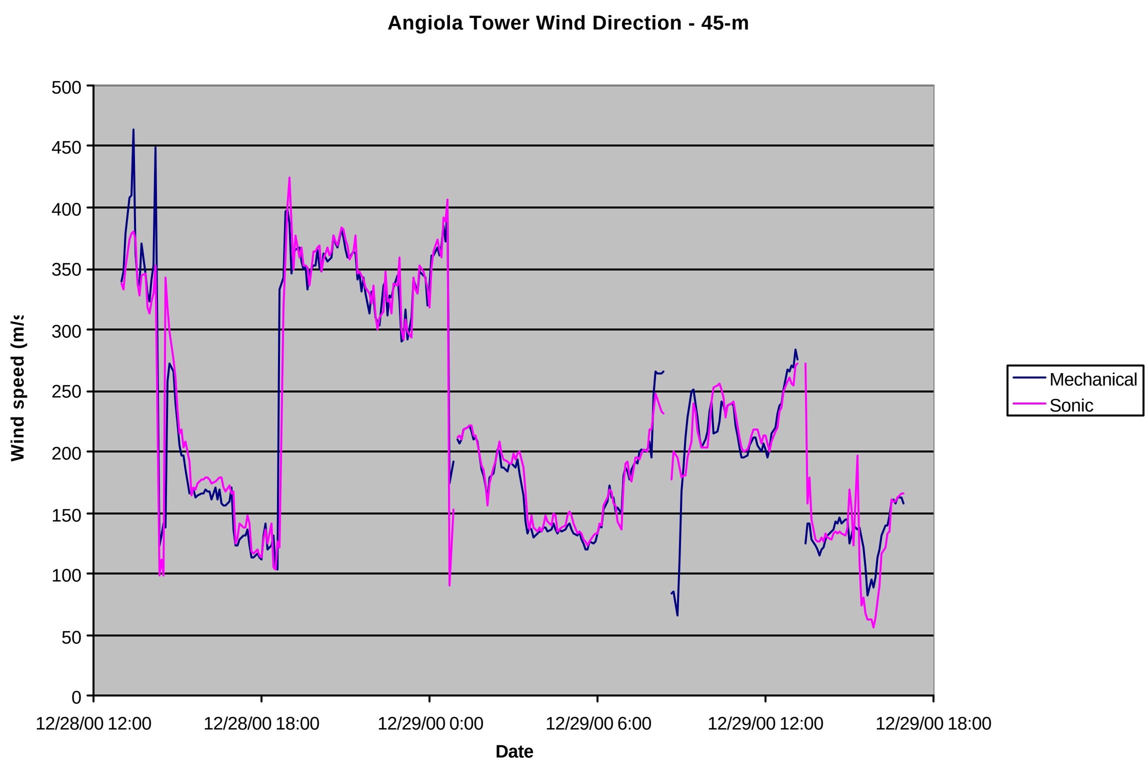


Figure 9. Wind direction comparison – 45-m level.

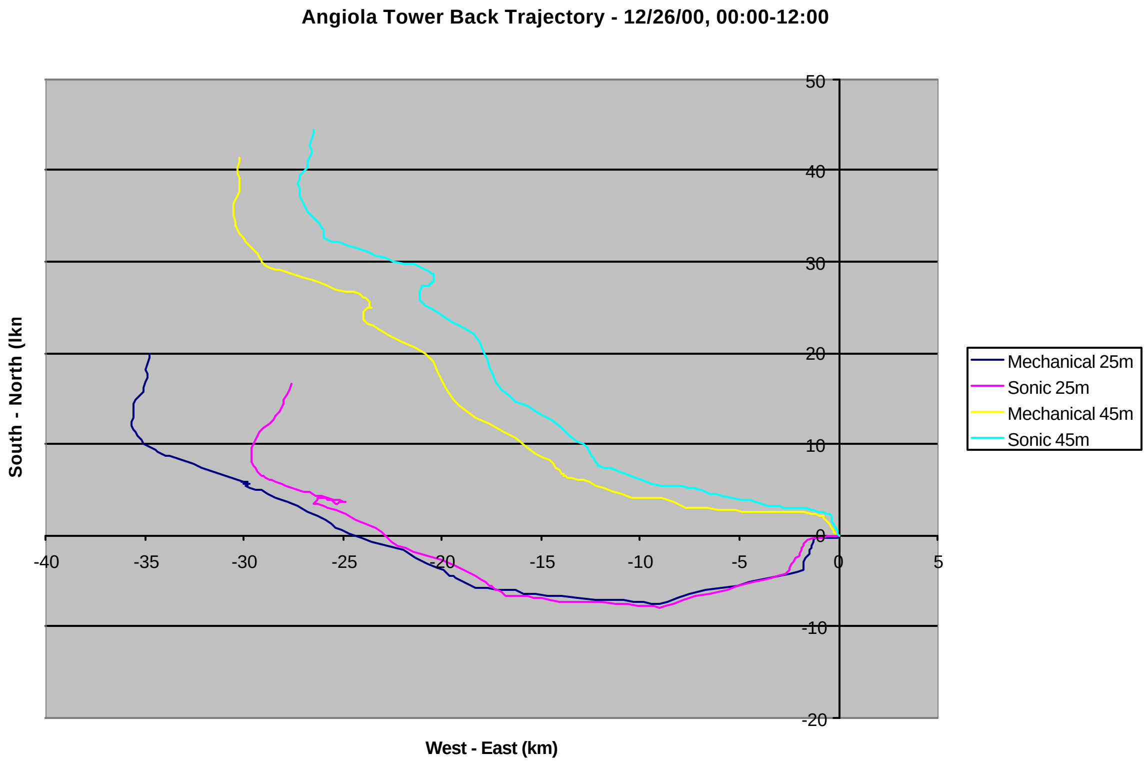


Figure 10. Back trajectory – winds from the northwest.

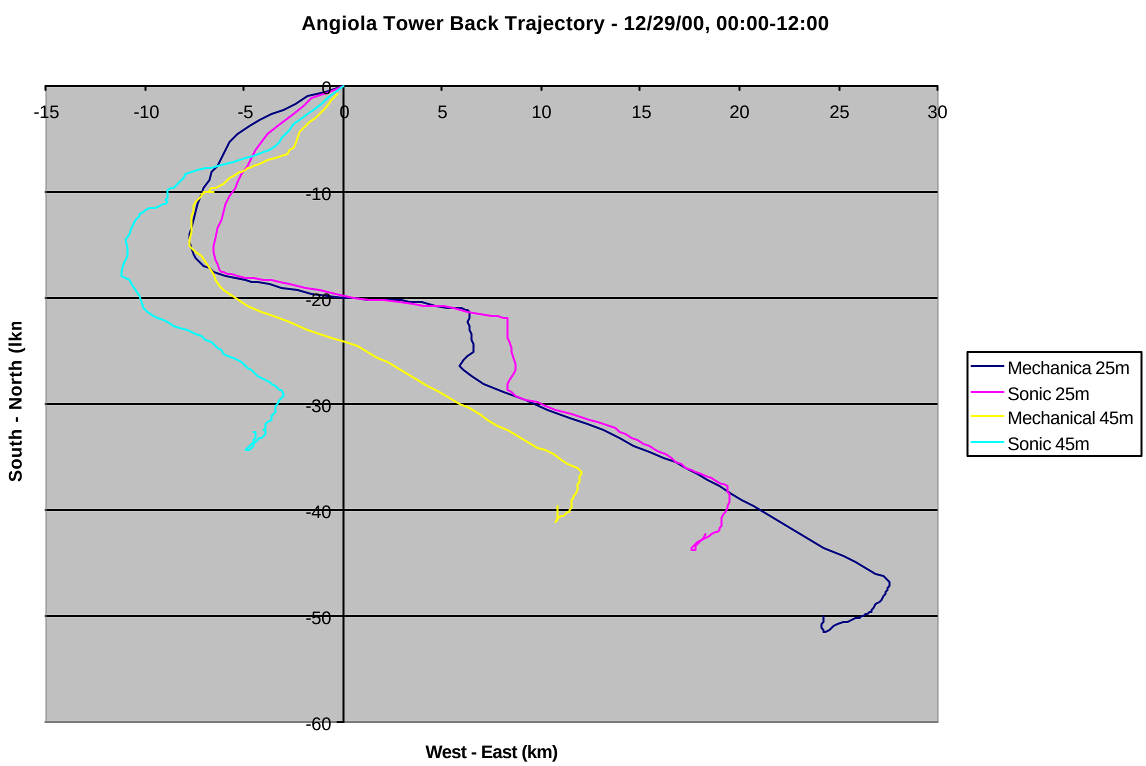


Figure 11. Back trajectory – winds from the southeast.